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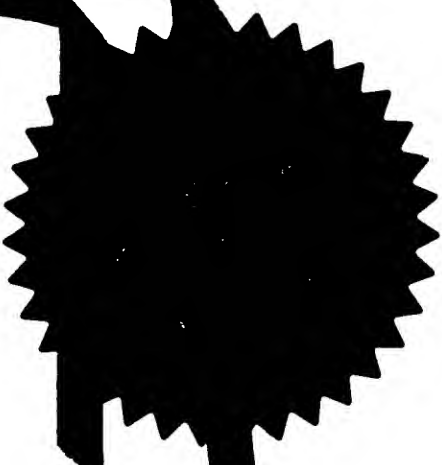
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# Request for grant of a patent

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DCR P20511GB

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3. Full name, address and postcode of the or of each applicant (underline all surnames)

Den Norske Stats Oljeselskap A.S.  
N-4035 Stavanger  
Norway

Patents ADP number (if you know it)

405829001

If the applicant is a corporate body, give the country/state of its incorporation

Norway

4. Title of the invention

Acid Gas Separation

5. Name of your agent (if you have one)

Kilburn & Strode

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

30 John Street  
London WC1N 2DD

20 Red Lion Street  
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WC1R 4PT

Patents ADP number (if you know it)

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Country

Priority application number  
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Date of filing  
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7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

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- a) any applicant named in part 3 is not an inventor, or
  - b) there is an inventor who is not named as an applicant, or
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Continuation sheets of this form

Description

15

Claim(s)

6

Abstract

1

Drawing(s)

4

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Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent (Patents Form 7/77)

Request for preliminary examination and search (Patents Form 9/77)

1

Request for substantive examination (Patents Form 10/77)

Any other documents (please specify)

11.

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12. Name and daytime telephone number of person to contact in the United Kingdom

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Fluid Separation System

The present invention relates to fluid separation systems. It is particularly concerned with the selective removal of a component or components from a mixture of gases using liquid solvent and is more particularly concerned with the absorption of acid gases such as  $\text{CO}_2$ ,  $\text{H}_2\text{S}$ , oxides of sulphur etc. from natural gas and from combustion gases.

Conventional systems for the absorption of acid gases employ a liquid solvent; typical solvents include tertiary amines such as methyldiethanolamine (MDEA), monoethanolamine (MEA) or diethanolamine (DEA). These solvents absorb  $\text{CO}_2$ ,  $\text{H}_2\text{S}$  and other acid gases. The solvent is contacted with the sour gas mixture (gas mixture including acid gases) in a column which may be a packed column, a plate column or a bubble-cap column, or a column with some other form of contact medium. In these systems, the gas and liquid streams flow countercurrently.

The prior art absorption systems suffer the disadvantage that in order to achieve a significant degree of gas/liquid contact, the columns have to be large and their operation is hampered by excessive foaming. In addition, the subsequent stripping section which removes the acid gas from solution must also be large, to handle the large volume of solvent used. Since the operation normally takes place under high pressure and the fluids involved are highly corrosive, the capital costs of the large columns and subsequent stripping section is high. Furthermore, operating costs and maintenance costs are high. Finally, these systems are generally capable only of reducing acid gas levels from perhaps 10% down to about 3% in the cleaned or "sweet"

gas.

It is an object of the present invention to provide a system for removing acid gas from a sour gas mixture which does not suffer from the disadvantages of the prior art.

More generally, it is an object of the invention to provide a method of selectively absorbing a fluid component from a fluid mixture with a high degree of efficiency and more economically than in existing methods.

According to one aspect of the invention, there is provided a method of removing acid gas components from a gas mixture which comprises: bringing the gas mixture into contact with a liquid solvent for the acid gases; subjecting the gas mixture and solvent to turbulent shear layer mixing conditions thereby causing the acid gas to be absorbed by the solvent; separating a gas phase and a liquid phase; and optionally treating the liquid phase to remove the absorbed acid gas components.

The invention also extends to the apparatus for carrying out this method.

The turbulent shear layer mixing is very intense and results in extremely efficient gas liquid contact. The gas entrained in the liquid may be in the form of bubbles which may generally fall within a size range of about 20 to 50  $\mu\text{m}$ . The efficient mixing means that absorption can take place very rapidly and in a relatively small amount of solvent compared to that required in conventional absorption columns. This in turn means that the liquid duty in the equipment is dramatically reduced resulting in a consequential reduction in the size of any downstream regeneration section. At the same time, the mixing system used is simple and inexpensive compared to prior art systems, leading to reduced costs. Finally, an

efficiency of approaching 100% for the removal of acid gas can be achieved.

5 In addition, conventional absorption methods involve the evolution of heat which must then be removed from the system. While the method of the invention is capable of operation with a relatively low pressure drop across the mixing means, when greater pressure drop is employed, a cooling effect is achieved and this may render the need for additional cooling unnecessary.

10 The absorption may be achieved by simply dissolving the gas or by way of a chemical reaction with the solvent.

15 Preferably, the method is carried out as a continuous process with the gas mixture and solvent flowing co-currently. The co-current flow eliminates the problems associated with foaming, since separation can easily be effected downstream of the mixer.

20 The turbulent shear layer mixing may be achieved by any convenient means, such as one or more nozzles, a jet pump or more preferably in a homogenising mixer comprising a vessel having a gas inlet, a liquid inlet and an outlet leading to a venturi passage, and a perforated tube extending from the outlet back into the vessel. In one regime, the gas mixture is supplied to the perforated tube and the liquid solvent is supplied to the vessel, and so the gas mixture draws the solvent into the venturi and the two phases are mixed. In another regime, the gas mixture is supplied to the vessel and the liquid solvent is supplied to the perforated tube, whereby the gas is drawn into the venturi by low pressure generated by the flow through the venturi, and the two phases are mixed. Alternatively, the liquid solvent and the gas mixture are both supplied to the vessel, the solvent being supplied to a level above the level of the

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outlet, whereby the gas is forced out through the outlet via the perforated tube, thereby drawing the solvent into the venturi so that the two phases are mixed. In a preferred embodiment, the tube is spaced from the periphery of the outlet, whereby the phase passing via the perforated tube draws the phase in the vessel at the outlet into the outlet via the space between the tube and the outlet. Such a mixer is supplied by Framo Engineering A/S and is described in EP-B-379319.

It will be appreciated that the invention is more broadly applicable than merely to the absorption of acid gas. Indeed, the principles of the invention may be applicable to any absorption application where the reaction kinetics are rapid.

Thus, the invention also extends to a method of selectively separating a component from a fluid mixture which comprises: forming a homogeneous mixture of the fluid with a liquid which contains a solvent or chemical reagent for the component to be removed, the homogeneous mixture being formed by subjecting the fluid and liquid phases to turbulent shear layer mixing conditions, separating a fluid phase and a liquid phase; and optionally treating the liquid phase to remove the absorbed gas component.

The fluid mixture may be a mixture of gases or may be in the liquid phase. The component to be separated may be a finely divided solid disperse phase, a dissolved solid, a liquid or a gas.

The invention also extends to the apparatus for carrying out this method.

The invention is also applicable to chemical reactions with fast reaction kinetics, where good mixing of the reactants is a requirement.

More generally, therefore, the invention may be



considered to extend to a method for effecting mass transfer between a first fluid and a second fluid, in which the first fluid includes a plurality of components and the second fluid includes a solvent or a reagent for a selected one of the components of the first fluid, the method comprising: subjecting the two fluids to turbulent shear layer mixing, thereby forming a homogeneous mixture, and allowing the selected component to be absorbed by the respective solvent or reagent in the second fluid.

Several of the components may be absorbed, either by a common solvent or reagent, or by respective solvents or reagents. In one possible regime, the first fluid is a gas mixture and the second fluid is in the liquid phase. In an alternative regime, the first fluid is a liquid mixture or a liquid solution and the second fluid in the liquid phase. In a further possible regime, the first fluid is a liquid mixture or a liquid solution and the second fluid is in the gas phase.

Again, the invention extends to the apparatus for carrying out these methods.

According to a more specific aspect of the invention, there is provided a method for removing a selected component from a mixture of gases which comprises: supplying the mixture of gases to a mixer; supplying a liquid including a solvent for the selected component to the mixer; subjecting the mixture of gases and the liquid to turbulent shear layer mixing in the mixer to form a homogeneous mixture; allowing the selected gas component to be absorbed by the solvent; cooling the homogeneous mixture; separating the cooled homogeneous mixture into a gas phase and a liquid phase in a hydrocyclone (or any other gas/liquid separator); removing the gas phase; subjecting the solvent in the

liquid phase to a regeneration treatment to remove the absorbed selected gas component; and recycling the regenerated solvent-containing liquid phase to the mixture.

5. Preferably, the regeneration is carried out by heating and/or by flashing off the absorbed gas component in a flash tank. Preferably, the post mixing cooling and the regenerative heating are achieved, at least in part by mutual heat exchange. Preferably, in instances where  
10 the gas mixture is at a low pressure, the liquid is pumped to the mixer and thereby draws the gas mixture with it through the mixer. Preferably, when the gas mixture is at high pressures, it is conveyed to the mixer at a high pressure and thereby draws the liquid with it  
15 through the mixer.

The invention also extends to apparatus for carrying out such a method, comprising: a turbulent shear layer mixer having a liquid inlet, a gas inlet and a fluid outlet; a cooler for the fluid stream from the fluid  
20 outlet; a hydrocyclone arranged to separate the cooled fluid stream into a gas phase and a liquid stream; a regenerator arranged to treat the separated liquid stream; and a recycle line arranged to convey the regenerated liquid stream to the mixer.

25 The apparatus may include a pump arranged to supply liquid to the liquid inlet of the mixer. Preferably, the regenerator is a heater and/or a flash tank. Preferably, the mixer is a homogenising mixer as described above, or alternatively a jet pump, or one or more nozzles.

30 The invention may be considered to extend to the use of a turbulent shear layer mixer to remove acid gas from a gas mixture such as natural gas or combustion gas by forming a homogeneous mixture of the gas mixture with a solvent for the acid gas in the mixer, allowing the acid

gas to be absorbed by the solvent, and subsequently separating a gas phase and a liquid phase, the liquid phase thereby containing the acid gas.

5 More generally, the invention may extend to the use of a turbulent shear layer mixer to effect selective mass transfer between a first fluid phase and a second fluid phase.

10 The preferred features of any of the various aspects of the invention described above may be equally applicable to the other aspects of the invention.

The separation/absorption/solution/reaction systems described are single operations, however it will be appreciated that multi separation/absorption/solution/reactions may be performed. These may be carried out  
15 simultaneously or sequentially and may also be carried out in series or in parallel.

The improved efficiency possible for the removal of acid gases makes the present invention particularly valuable as awareness is increased of the potential  
20 damage to the environment that can be caused by acid gases in effluents such as combustion gas.

Furthermore, the small size of the apparatus compared to conventional absorption columns render the invention especially applicable to use in marine  
25 applications, such as on board shuttle tankers.

The invention may be put into practice in various ways and two specific embodiments will be described by way of example to illustrate the invention with reference to the accompanying drawings, in which:

30 Figure 1 is a flow diagram of the process for use when the gas is under low pressure;

Figure 2 is a flow diagram of the process for use when the gas is under high pressure;

Figure 3 is a block diagram of the apparatus as used

in the batch test procedure;

Figure 4 is a view of the mixer as used in the batch test procedure; and

5 Figure 5 is a view of a jet pump which can be used as an alternative to the mixer.

10 In one embodiment of the invention, a continuous process operation for the removal of carbon dioxide (and other acid gases) from exhaust gas is shown in figure 1. A liquid solvent stream 1, for example MEA (monoethanolamine), is conducted by a pump 2 to a mixer 3 (though this could be an ejector) capable of inducing turbulent shear layer mixing. An exhaust gas stream 4, including the  $\text{CO}_2$  which is to be removed, is drawn into the mixer 3 by the low pressure generated in the venturi by the liquid stream after it has passed through the pump (stream 1a). This arrangement provides an automatic means of self-regulation as the gas mixture to solvent ratio can be maintained for varying flow rates. At the outlet of the mixer 3 the liquid solvent and the exhaust gas stream are in the form of a homogeneous mixture (stream 5) and the mass transfer of the  $\text{CO}_2$  from the gas phase to the liquid occurs very rapidly.

20 The mixed two phase stream 5 is then conveyed to a cooler 6 and on into a hydro cyclone 7. The gas stream 8 is taken off and the liquid stream 9 passes on to a regeneration system. At this point in the circuit all the  $\text{CO}_2$  is in the liquid phase (stream 9) and the gas stream 8 is free of  $\text{CO}_2$ .

30 The regeneration of the liquid solvent is achieved by boiling off the  $\text{CO}_2$  in a heater 10. The  $\text{CO}_2$  is taken off as a gas stream 11 and the liquid solvent is optionally passed through a flash tank (not shown) to remove any residual dissolved gas before being recycled into the feed stream 1. The liquid solvent in stream 1 is

topped up from the reservoir 12 as necessary to maintain a regular flow rate around the system.

It will be clear to a person skilled in the art that the cooler 6 and the heater 10 may be combined to form a heat exchange unit.

An alternative system for the removal of  $\text{CO}_2$  from a high pressure gas stream is shown in figure 2. A high pressure gas stream 20 containing the  $\text{CO}_2$  which is to be removed is conveyed to a mixer unit 21 similar to that shown in figure 4. The high pressure of the gas draws a controlled amount of liquid solvent, for example MEA, from the recycle stream 22 and, if necessary, from a reservoir 23 into the mixer 21.

At the outlet of the mixer 21 the two phases are in the form of a homogeneous mixture (stream 24) and the mass transfer of the  $\text{CO}_2$  from the gas phase to the liquid solvent takes place. The residence time may be as little as 0.1 seconds since the reaction kinetics for the absorption of  $\text{CO}_2$  by MEA are very rapid, although this will vary with the solvent used and the gas to be transferred from the gas to the liquid.

The two phase mixture (stream 24) passes through a cooler 25 to a hydro cyclone unit 26. The gas stream free of  $\text{CO}_2$  is taken off in stream 27 and the remaining liquid stream 28 including the  $\text{CO}_2$  is passed to a regeneration system.

The liquid stream 28 is fed into a heater 29 to remove the  $\text{CO}_2$  as a gas stream 30. This regenerates the solvent for re-use in the system. This solvent (stream 22) is then drawn into the mixer 21 by the low pressure generated in the venturi by the high pressure gas (stream 20) as explained above. Any shortfall in the solvent liquid is made up by addition from the reservoir 23. As in the first embodiment, the heater 29 and the cooler 25

can be combined to form a heat exchange unit.

The mixer used in both the above embodiments is shown in figure 4. The homogenising mixer 100 comprises a vessel 101 having a gas inlet 102, a liquid inlet 103 and an outlet 104 leading to a venturi passage 105. There is a perforated tube 106 extending from the outlet 104 back into the vessel 101.

In a first arrangement, the gas mixture is supplied to the vessel 101 and the liquid solvent is supplied to the perforated tube 106 whereby the gas is drawn into the venturi by the liquid and the two phases are mixed.

In a second arrangement, the liquid solvent and the gas mixture are supplied to the vessel 101, the solvent being supplied to a level above the level of the outlet 104, whereby the gas is forced out through the outlet 104 via the perforated tube 106, thereby drawing the solvent into the venturi so that the two phases are mixed.

The mixers referred to in the above embodiments may be replaced by jet pump arrangements which are capable of inducing turbulent shear layer mixing. Figure 5 shows a jet pump 120 comprising a first fluid inlet 121 for the high pressure fluid and a second fluid inlet 122 for the low pressure fluid. The high pressure fluid draws the low pressure fluid along the length of the jet pump 120 to the outlet 123. The fluids are well mixed into a homogenised mixture in the region 124 at the outlet of the high pressure inlet 121.

The mixer or jet pump arrangement may also be replaced by a series of nozzles or any other mixing arrangement which can induce turbulent shear layer mixing in a gas/liquid co-current flow regime. These alternatives are not shown here.

The invention is further illustrated by reference to the following examples. These serve to verify the

operating principles of the two embodiments described. In the series of batch experiments conducted, the gas stream was a mixture of nitrogen ( $N_2$ ) and  $CO_2$  and the liquid solvent was a mixture of MEA and water. The reservoir pipe was kept under pressure using nitrogen gas. The mixer used was a FRAMO mixer generally as described in EP 379319 and shown in figure 4. The mixer injection pipe was adjusted to yield gas/liquid ratios in the range of about 3 to 5, depending upon the total flow rate.

A schematic diagram for the series of experiments is shown in figure 3. The mixer 51 is charged with an amount of the liquid solvent mixture from the reservoir 54 which is controlled by a valve 55. A gas source 50 of the experimental  $N_2/CO_2$  gas mixture is conveyed to the mixer 51 via a pipe 52 controlled by a valve 53.

At the outlet of the mixer 51 there is a 1 metre section of pipe 56 in which the mass transfer occurs. This section provides the residence time for the contacting materials. A set of 2 simultaneously acting fast closing valves 57 and 58 form a 1.5 metre analysis section 59 where the gas/liquid mixture can be captured, separated and sampled. At the top end of the analysis section there is a sampling point where a sample of the gas can be drawn off (not shown). At the lower end of the section there is a further sampling point where a sample of the liquid can be drawn off (not shown). The lower section of the sampling section is provided with means for cooling the liquid sample prior to its removal (not shown for clarity).

A further valve 60 separates the sampling section from a reservoir pipe 61 and is used to control the flow rate through the system. The reservoir pipe 61 is pressurised to a predetermined pressure by an independent nitrogen gas source 62 via a pipe 63 controlled by a

valve 64. This pressure will be lower than that in the mixer to provide a pressure difference which will force the fluids through the system. The reservoir pipe 61 is inclined with respect to the horizontal to enable the liquid collected to be drained off via a pipe 65 controlled by a valve 66 to a measurement drum 67 which is used to determine the amount of liquid passing through the system on each run. The drum 67 has a drainage pipe 68 controlled by a valve 69.

10 In operation, the mixer 51, pipe section 56 and analysis section 59 are filled with the suitable strength solvent solution. The simultaneously acting valves 57 and 58 are closed and valve 60 is set to a position carefully adjusted to yield the required mass flow rate through the system for the predetermined pressure difference between the mixer and the reservoir pipe.

15 The mixer 51 is pressurised with the test gas of CO<sub>2</sub>-rich nitrogen to a pressure of 50 barg. The reservoir pipe 61 is pressurised with nitrogen to a predetermined value typically between 16 and 48 barg, providing a range of flow rates through the system.

20 Before the experiment starts, a sample of the test gas is taken to determine the level of CO<sub>2</sub> in the gas. The experiment commences with the activation of the simultaneously operating valves 57 and 58. The liquid and the gaseous solution flow co-currently through the system to the reservoir pipe 61. The pressure in the mixer is maintained at 50 barg during the 10 second test run by manual supply of the test gas from a cylinder fitted with an accurate manometer. This makes it possible to record the amount of spent gas for each experiment.

25 30 After 10 seconds the 2 operating valves 57 and 58 are closed simultaneously. A sample of gas from the analysis section is extracted from the upper sampling



point immediately after the valves have closed. This is then tested for content of CO<sub>2</sub> by gas chromatography. The machine used was a Chromopack Model CP-2002 gas chromatograph.

5           In order to verify the mass balance, a liquid sample of the amine solution in the analysis section is taken from the lower sampling point. Before the sample is taken the liquid in the analysis section is cooled using nitrogen gas surrounding the pipe section 59. The liquid  
10 sample is analyzed using a titration technique specially developed for CO<sub>2</sub>.

          At the end of each run, the liquid from the reservoir pipe 61 is released into the measurement drum  
15 67 to measure the amount of liquid expended in the course of the run.

The results of the tests are shown in Table 1 below:

	MEA wt%	mol% CO <sub>2</sub> in exit gas	gas flow rate (m <sup>3</sup> /hr)	liquid flow rate (m <sup>3</sup> /hr)	total flow rate (m <sup>3</sup> /hr)	gas volume fraction
	50	0.005	10.34	4.63	14.97	0.69
5	50	0.003	11.76	3.92	15.68	0.75
	50	0.005	12.12	3.92	16.04	0.76
	50	0.002	10.87	3.92	14.79	0.73
	50	0.006	10.08	3.96	14.04	0.72
	50	0.007	11.7	3.6	15.3	0.76
10	50	0.019	10.44	3.24	13.68	0.76
	50	0.006	7.2	3.24	10.44	0.69
	50	0.007	15.48	3.24	18.72	0.83
	25	0.009	10.08	4.68	14.76	0.68
	25	0.005	9	3.96	12.96	0.69
15	25	0.006	9	3.96	12.96	0.69
	25	0.003	6.84	3.6	10.44	0.66
	25	0.005	14.04	4.32	18.36	0.76
	5	2.03	14.4	3.6	18	0.80
	5	0.5	15.12	3.24	18.36	0.82
20	5	2.95	17.28	3.24	20.52	0.84
	5	3.65	18.72	1.8	20.56	0.91
	5	1.63	12.6	3.96	16.56	0.76
	5	2	14.76	3.96	18.72	0.79
	5	2.13	15.84	3.6	19.44	0.81
25	5	0.31	7.92	3.6	11.52	0.69
	5	1.25	7.92	3.6	11.52	0.69
	5	2.32	10.44	3.6	14.04	0.74
	5	2.67	11.16	3.6	14.76	0.76
30	5	3.4	18	3.6	21.6	0.83

In all cases the gas feed composition was 10.5 mol per

cent CO<sub>2</sub> in nitrogen.

5 The results show that virtually all the CO<sub>2</sub> is absorbed from the gas to the liquid solvent for the 50% and 25% mixture for all the flow rates tested. Only on reduction of the MEA concentration to a mere 5% by weight does the amount of CO<sub>2</sub> remaining in the gas reach appreciable levels.

10 From the measurements at the 5% level, it can be seen that the absorption efficiency decreases with an increasing gas flow rate and gas volume fraction. This result is expected since the already lean solvent mixture (only 5% MEA) has a diminishing capacity to absorb all of the CO<sub>2</sub>.

15 The gas chromatograph measurements of the CO<sub>2</sub> were verified using the data obtained from the titration of the liquid sample. A mass balance calculation on the CO<sub>2</sub> through the system showed that the CO<sub>2</sub> which was in the test gas had been transferred to the liquid.

20 It will be apparent to a person skilled in the art that the above results are not dependent upon the gas to be absorbed or on the solvent used to absorb that gas. Therefore it is clear that the above method of selective transfer of a gas from a mixture of gases to a liquid solvent for that gas is applicable to any gas and any  
25 respective solvent.

## Claims:

1. A method of removing acid gas components from a gas mixture which comprises: bringing the gas mixture into contact with a liquid solvent for the acid gases; 5  
subjecting the gas mixture and solvent to turbulent shear layer mixing conditions thereby causing the acid gas to be absorbed by the solvent; separating a gas phase and a liquid phase; and optionally treating the liquid phase to remove the absorbed acid gas components.
- 10 2. A method as claimed in Claim 1, in which the method is carried out as a continuous process with the gas mixture and solvent flowing co-currently.
- 15 3. A method as claimed in Claim 2, in which the mixing is conducted in a homogenising mixer comprising a vessel having a gas inlet, a liquid inlet and an outlet leading to a venturi passage, and a perforated tube extending from the outlet back into the vessel.
- 20 4. A method as claimed in Claim 3, in which the gas mixture is supplied to the perforated tube and the liquid solvent is supplied to the vessel, and so the gas mixture draws the solvent into the venturi and the two phases are
- 25 mixed.
5. A method as claimed in Claim 3, in which the gas mixture is supplied to the vessel and the liquid solvent is supplied to the perforated tube, whereby the gas is
- 30 drawn into the venturi by the liquid and the two phases are mixed.
6. A method as claimed in Claim 3, in which the liquid solvent and the gas mixture are supplied to the vessel,

the solvent being supplied to a level above the level of the outlet, whereby the gas is forced out through the outlet via the perforated tube, thereby drawing the solvent into the venturi so that the two phases are mixed.

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7. A method as claimed in any of Claims 3 to 6, in which the tube is spaced from the periphery of the outlet, whereby the phase passing via the perforated tube draws the phase in the vessel at the outlet into the outlet via the space between the tube and the outlet.

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8. A method as claimed in Claim 2, in which the mixing is conducted in a jet pump.

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9. A method as claimed in Claim 2, in which the mixing is conducted by passing the liquid solvent through one or more nozzles in a stream of the gas mixture.

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10. A method of selectively separating a component from a fluid mixture which comprises: forming a homogeneous mixture of the fluid with a liquid which contains a solvent or chemical reagent for the component to be removed, the homogeneous mixture being formed by subjecting the fluid and liquid phases to turbulent shear layer mixing conditions, separating a fluid phase and a liquid phase; and optionally treating the liquid phase to remove the absorbed gas component.

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11. A method as claimed in Claim 10, in which the fluid mixture is a mixture of gases.

12. A method as claimed in Claim 10, in which the fluid mixture is in the liquid phase.

13. A method as claimed in Claim 12, in which the component to be separated is a finely divided solid disperse phase, a dissolved solid, a liquid or a gas.

5 14. A method for effecting mass transfer between a first fluid and a second fluid, in which the first fluid includes a plurality of components and the second fluid includes a solvent or a reagent for a selected one of the components of the first fluid, the method comprising:  
10 subjecting the two fluids to turbulent shear layer mixing, thereby forming a homogeneous mixture, and allowing the selected component to be absorbed by the respective solvent or reagent in the second fluid.

15 15. A method as claimed in Claim 14, in which a plurality of components are absorbed, either by a common solvent or reagent, or by respective solvents or reagents.

20 16. A method as claimed in Claim 14 or Claim 15, in which the first fluid is a gas mixture and the second fluid is in the liquid phase.

25 17. A method as claimed in Claim 14 or Claim 15, in which the first fluid is a liquid mixture or a liquid solution and the second fluid in the liquid phase.

30 18. A method as claimed in Claim 14 or Claim 15, in which the first fluid is a liquid mixture or a liquid solution and the second fluid is in the gas phase.

19. A method for removing a selected component from a mixture of gases which comprises: supplying the mixture of gases to a mixer; supplying a liquid including a

solvent for the selected component to the mixer; subjecting the mixture of gases and the liquid to turbulent shear layer mixing in the mixer to form a homogeneous mixture; allowing the selected gas component  
5 to be absorbed by the solvent; cooling the homogeneous mixture; separating the cooled homogeneous mixture into a gas phase and a liquid phase in a hydrocyclone; removing the gas phase; subjecting the solvent in the liquid phase to a regeneration treatment to remove the  
10 absorbed selected gas component; and recycling the regenerated solvent-containing liquid phase to the mixture.

20. A method as claimed in Claim 19, in which the  
15 regeneration is carried out by heating and/or by flashing off the absorbed gas component in a flash tank.

21. A method as claimed in Claim 20, in which the post-mixing cooling and the regenerative heating are achieved,  
20 at least in part by mutual heat exchange.

22. A method as claimed in any of Claims 19 to 21, in which the liquid is pumped to the mixer and thereby draws the gas mixture with it through the mixer.  
25

23. A method as claimed in any of Claims 19 to 21, in which the gas mixture is conveyed to the mixer at a high pressure and thereby draws the liquid with it through the mixer.  
30

24. Apparatus for carrying out the method of Claim 19, comprising: a turbulent shear layer mixer having a liquid inlet, a gas inlet and a fluid outlet; a cooler for the fluid stream from the fluid outlet; a hydrocyclone

arranged to separate the cooled fluid stream into a gas phase and a liquid stream; a regenerator arranged to treat the separated liquid stream; and a recycle line arranged to convey the regenerated liquid stream to the mixer.

5

25. Apparatus as claimed in Claim 24, including a pump arranged to supply liquid to the liquid inlet of the mixer.

10

26. Apparatus as claimed in Claim 24 or Claim 25, in which the regenerator is a heater and/or a flash tank.

15

27. Apparatus as claimed in any of Claims 24 to 26, in which the mixer is a homogenising mixer comprising a vessel having a gas inlet, a liquid inlet and an outlet leading to a venturi passage, and a perforated tube extending from the outlet back into the vessel.

20

28. Apparatus as claimed in claim 27, in which the perforated tube is spaced from the periphery of the outlet.

25

29. Apparatus as claimed in any of Claims 24 to 26, in which the mixer is a jet pump.

30

330 The use of a turbulent shear layer mixer to effect selective mass transfer between a first fluid phase and a second fluid phase.

31. The use of a turbulent shear layer mixer to remove acid gas from a gas mixture such as natural gas or combustion gas by forming a homogeneous mixture of the gas mixture with a solvent for the acid gas in the mixer,



allowing the acid gas to be absorbed by the solvent, and subsequently separating a gas phase and a liquid phase, the liquid phase thereby containing the acid gas.

## Abstract

5       The use of a turbulent shear layer mixer to effect  
selective mass transfer between a first fluid phase and  
a second fluid phase. The invention particularly applies  
to a method of removing acid gas components from a gas  
mixture which comprises: bringing the gas mixture into  
contact with a liquid solvent for the acid gases;  
10       subjecting the gas mixture and solvent to turbulent shear  
layer mixing conditions thereby causing the acid gas to  
be absorbed by the solvent; separating a gas phase and a  
liquid phase; and optionally treating the liquid phase to  
remove the absorbed acid gas components.

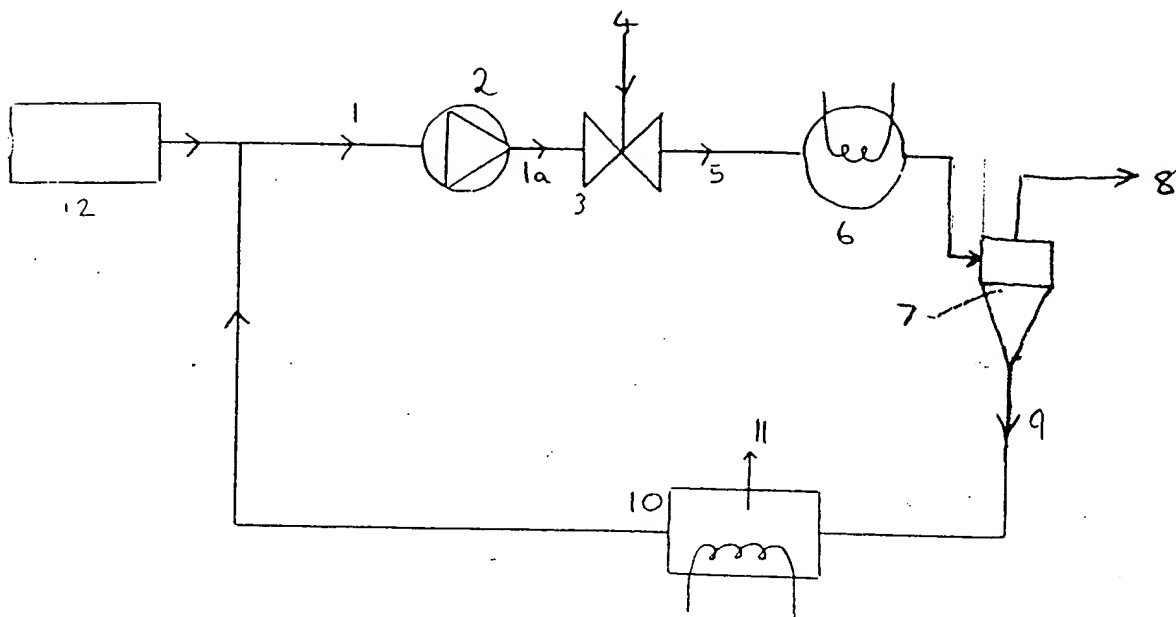


FIG 1

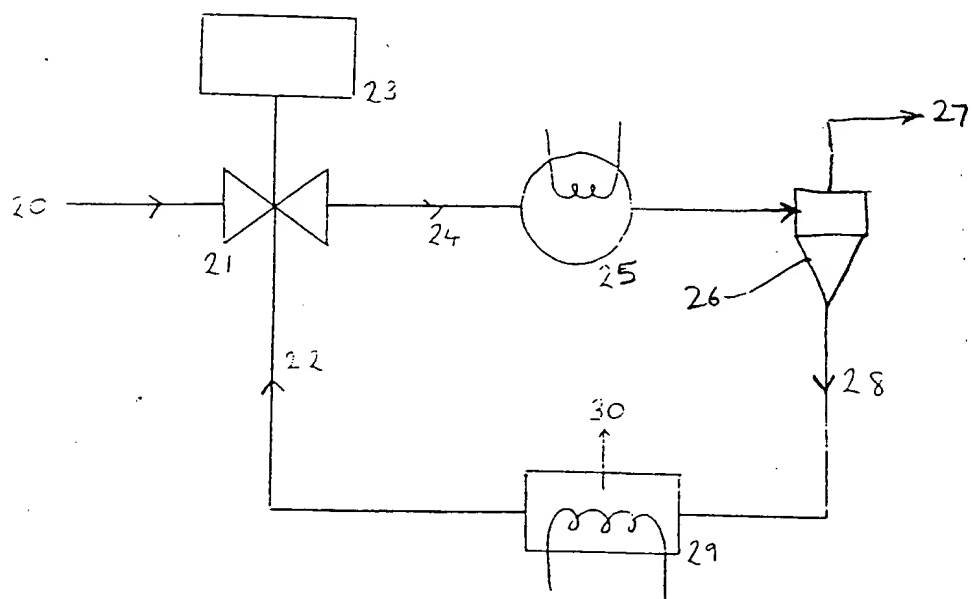


FIG 2

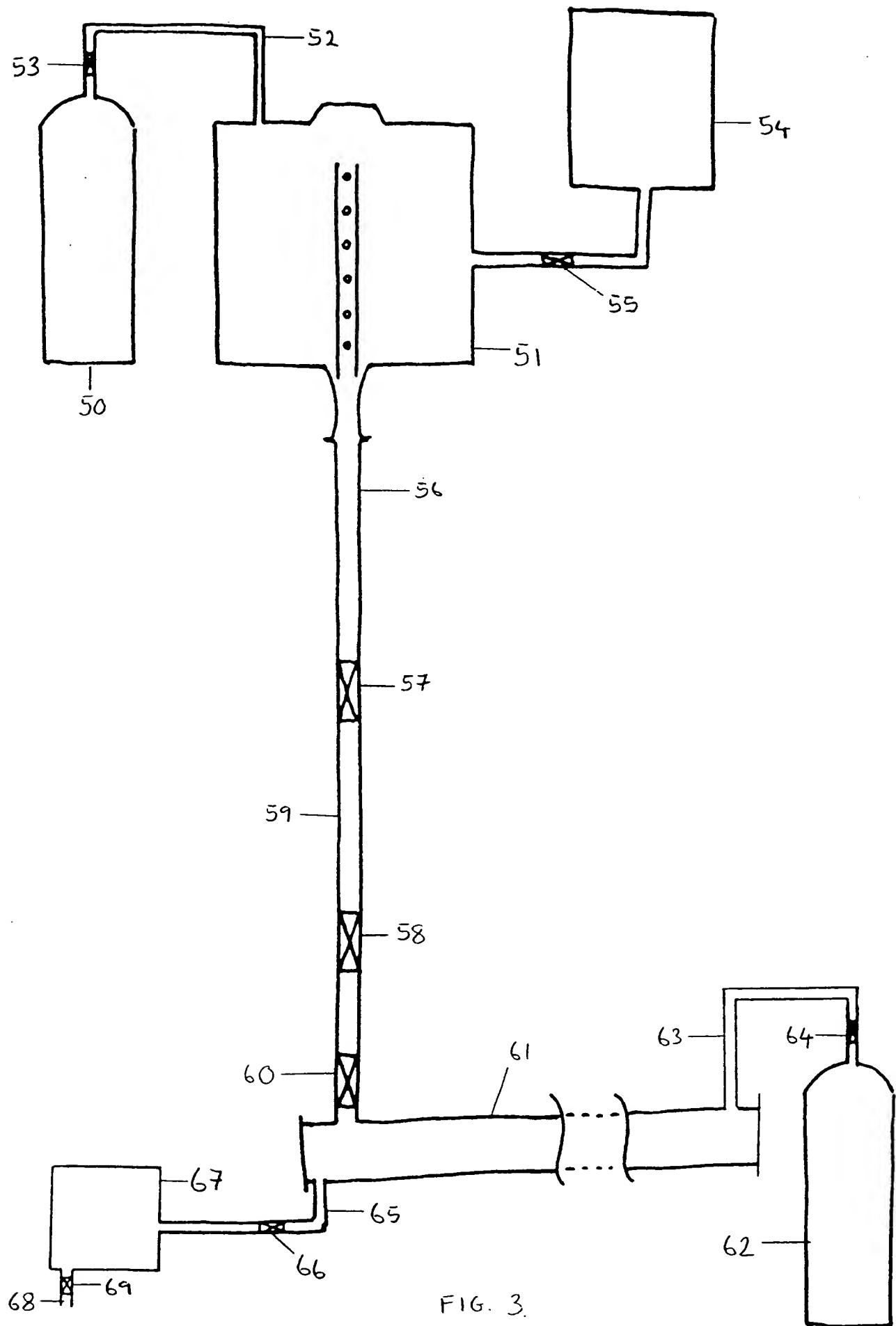


FIG. 3.

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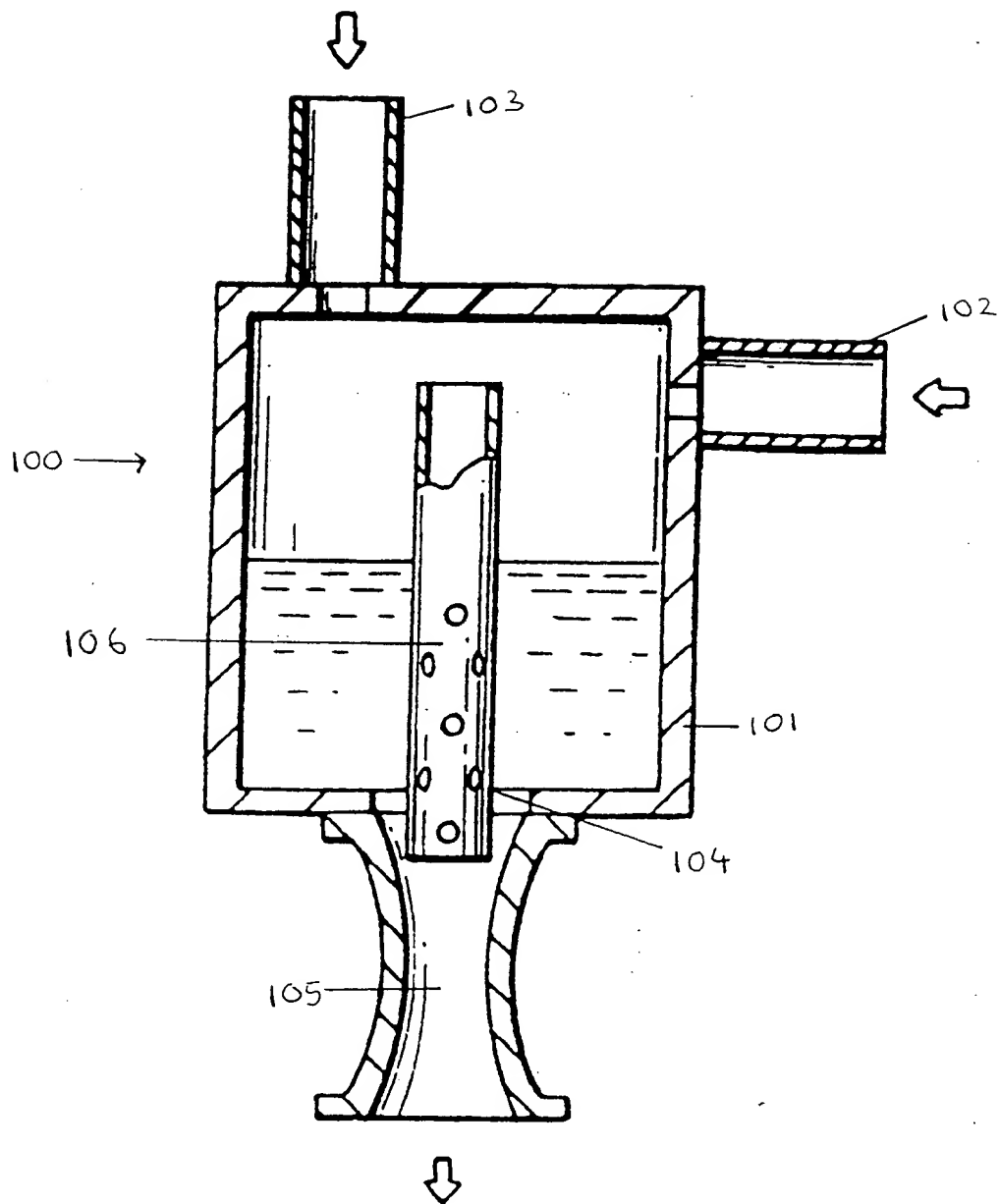


FIG. 4

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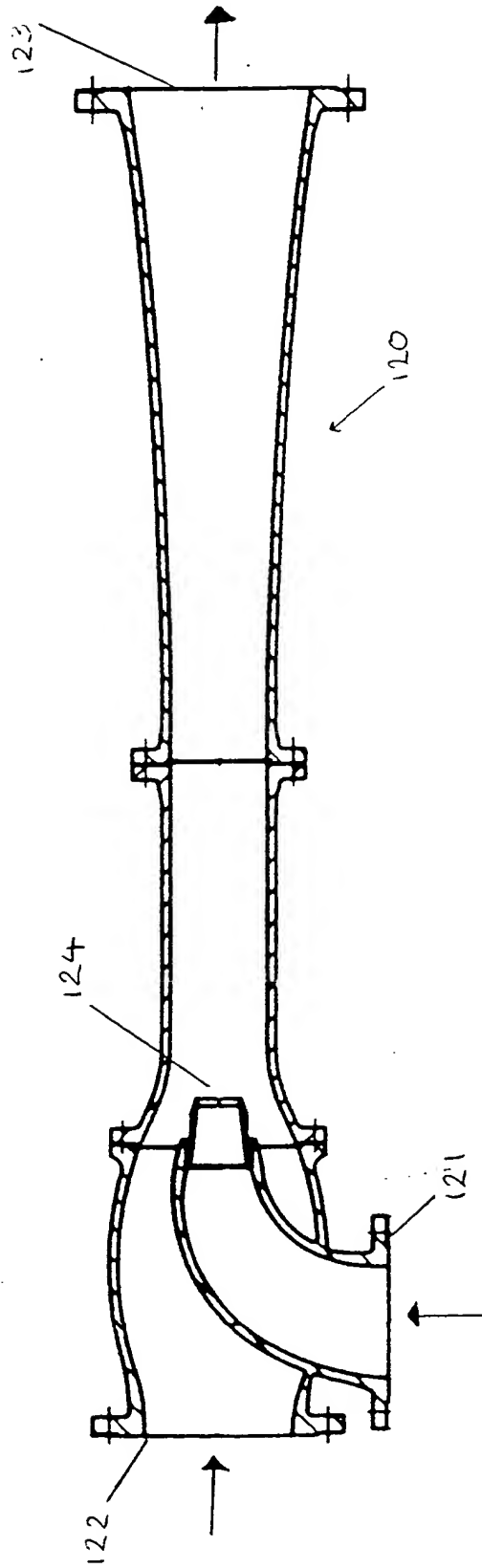


FIG. 5.